1966

The Effect of Development time, Temperature, and Sulfite Content on the Acutance of a Photographic Emulsion

Jeffrey Waltzer

The Effect Of Development Time, Temperature, And Sulfite Content On The Acutance Of A Photographic Emulsion.

by Jeffrey Waltzer

May 12, 1966

Senior Research Project

Rochester Institute Of
Technology

Abstract

Acutance of Plus-X film was examined as a function of development time, temperature, and sulfite content. Five levels of each factor were used with equal increments respectively. Method of printing knife-edge targets and noting the extent of edge-effects was also sought for. Acutance was found to increase with increasing development time and temperature but decreased when the sulfite content of the developer exceeded the recommended amount.

Introduction

Acutance is the physical measure of the psychological concept of sharpness. It is defined as $\langle G_x^2 \rangle$av./ DS; where $\langle G_x^2 \rangle$av. is obtained by taking successive gradients, $G=\Delta D/\Delta X$ of a microdensitometer trace of a knife-edge target printed on an emulsion, squaring each value, summing up all the values, and lastly dividing by the number of values. DS is the density difference between the developed knife-edge image and the background of the image.[1] This value of acutance correlates well with the sensation of sharpness with the coefficient of correlation being 0.994.[2] Therefore only the physical measure of sharpness (acutance) will be used to report the data in this experiment.

There are several articles to be found in the literature of Photographic Science dealing with acutance in theory and concept. The only really pertinent data to this experiment can be found in articles written by H.Frieser and in an artical written jointly by J.H.Altman and R.W.Henn.

Frieser investigated edge-effects as a function of development time, temperature, and dilution.[3] There does not seem to be much known about the relationship between edge-effects and acutance but it is safe to say that since acutance deals strictly with edge-gradients and density difference as explained previously, an increased or decreased adjacency effect would certainly affect the measurement of acutance. Frieser expressed edge-effect as the excess density at the top of the trace divided by the maximum density level. He found that edge-effect increased with increasing development temperature and increasing developer dilution but reached a constant value with increasing development time. It

is this fact that differs with most of the other literature. It is generally believed that edge-effects begin to vanish when development approaches completion. This experiment will try to verify or disprove Frieser's findings in relation to what happens to acutance as development time increases.

Altman and Henn[4] investigated acutance as a function of developer composition. They varied the metol and sulfite content of the developer and tested three different emulsions. The resulting changes in acutance depended on the particular emulsion involved. The results showed that large amounts of sulfite in connection with a high and constant metol concentration caused a decrease in acutance. When the sulfite content was low and constant, moderate improvements in acutance resulted when metol concentration was lowered. Acutance continued to increase to the lowest metol concentration tried- 0.25 gr/lit.

These two articles are all that specifically deal with development effects on acutance. There are articles involving acutance enhancement by the addition of various exotic type chemicals[5] and some articles in Russian, German, Japanese, and Hungarian. This experiment is relatively straightforward and basic but the data it hopes to report can be seen nowhere in the literature. The experiment hopes to extend the findings of Frieser, Altman and Henn and possibly bridge the gap from there initial findings to some more concrete knowledge by providing some specific data for the emulsion under question in regards to what happens to acutance when development time, temperature, and sulfite content are varied.

Objectives

Hypothesis: The acutance of a photographic emulsion is affected by development time, temperature, and sulfite content.

Primary Objectives

A) By gathering data, drawing curves, and making a statistical analysis, the hypothesis will be accepted in full or part or rejected entirely.

B) By means of the data, curves, and statistical analysis, it will be determined how each factor separately affects (if at all) the acutance of the emulsion under test. If possible an equation of relationship will be formulated for the emulsion by means of regression analysis.

C) An attempt at a reasonable explanation of each factor's contribution to acutance will be formulated.

Secondary Objectives

D) The extent of the edge-effect caused by variations in development time, temperature, and sulfite content will be noted.

E) A satisfactory method of making knife-edge exposures will be sought for.

F) Determining whether or not brush development seems to produce a more uniform image with respect to even density throughout and the minimizing of edge-effects.

Experimental Procedure

Method of Exposing a Knife-Edge Target on Film

The method used in this experiment was not originally planned. It seems necessary at this point to briefly outline the originally planned method and to explain why it was found to be unsatisfactory.

A National Bureau Of Standards knife-edge printed on glass was to be placed in the precision camera and projected onto the film at a 50X reduction. This method is not recommended because: 1. good focus could only be obtained after several exposures and could not be repeated because of inherent difficulties in the precision camera and 2. a halo of density around the edge and blotches of density appeared throughout the image. This factor was also prominent when the target was projected using an enlarger; leading to the conclusion that projecting an edge target is a poor method of obtaining a knife-edge image.

Exposure series always needed

The method used in this experiment was to blacken the edge of a stainless steel razor blade with matte black paint and to place this directly on top of the film at a 45° angle with it and "contact print" it using an enlarger as the light source. It was felt that the elimination of the lens factor in projection printing would enhance the image. This method however was also found to be poor but the images obtained at least lent themselves to analysis. The conclusion here is that methods beside projecting and contact printing a knife-edge target must be found.

!!!

Preliminary Experiment

A desirable level of exposure and development time will be sought for here in order to produce a pre-determined maximum density difference across the edge (2.2 for Plus-X and

D-76 in this experiment). The enlarger lens should be closed all the way down to facilitate a point source and exposure time should be kept to a workable minimum. This will reduce reflections off the edge. Distance from light source to film should be used to vary the exposure level.

Stage One

1. Expose fifteen sheets of film under the conditions found in the preliminary experiment that gives the desired density difference across the edge.
2. Process one sheet of film for each of the following conditions a) the time found in the preliminary experiment to obtain the desired density difference and one sheet b) two minutes more c) four minutes more d) two minutes less and e) four minutes less. Development temperature and sulfite content are constant.
3. Process one sheet of film under the conditions of 2a above, one sheet a) five degrees more b) ten degrees more c) five degrees less and d) ten degrees less. Development time and sulfite content are constant.
4. Process one sheet of film under the conditions of 2a above, one sheet a) with 125 gr/lit. sulfite b) with 150 gr/lit. sulfite c) with 75 gr/lit. sulfite and d) with 50 gr/lit. of sulfite. Development time and temperature are constant.
5. Make a microdensitometer trace of each edge. Three portions of each edge should be read making a total of forty-five traces.
6. Calculate acutance of each trace.

Stage Two

1. Repeat steps 1-6 of stage one
2. take the combined data of each stage and draw curves of relationship (i.e. time-acutance, temperature-acutance, and sulfite content-acutance). Also make a chart form of the data.
3. By means of regression analysis try to determine equations of the relationship and test for their validity.
4. Discuss results and draw logical conclusions.

Results

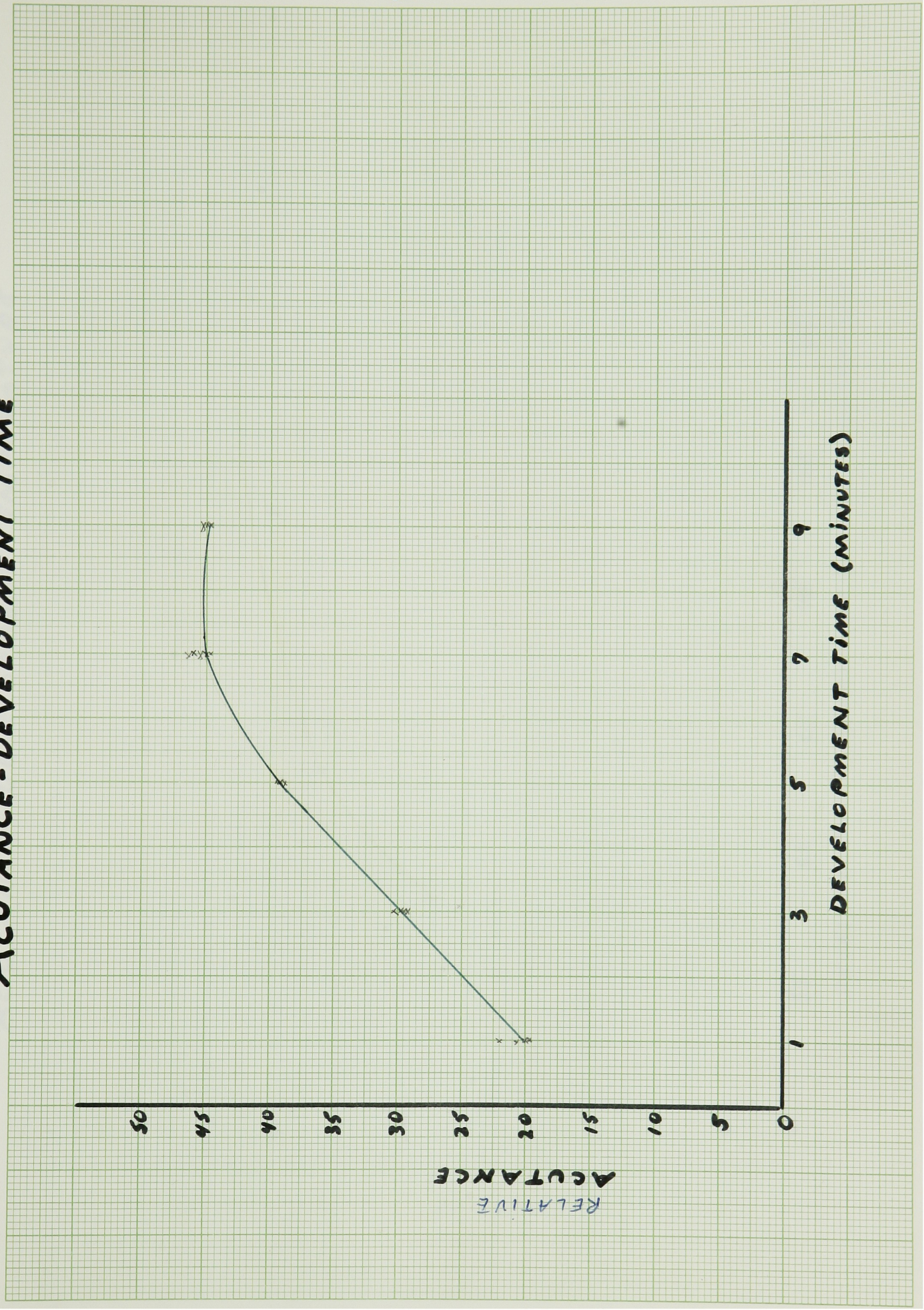
ACUTANCE°°

TIME	EDGE ONE			EDGE TWO			AVERAGE
1 Minute	20.0	20.2	20.0	19.8	20.1	20.0	20.0
3 Minutes	29.7	29.4	29.6	30.0	29.7	29.9	29.7
5 Minutes	39.1	39.4	39.2	39.6	39.6	39.6	39.4
7 Minutes	44.6	45.1	45.0	45.0	45.2	45.1	45.0
9 Minutes	44.6	44.6	44.7	44.5	44.6	44.6	44.6

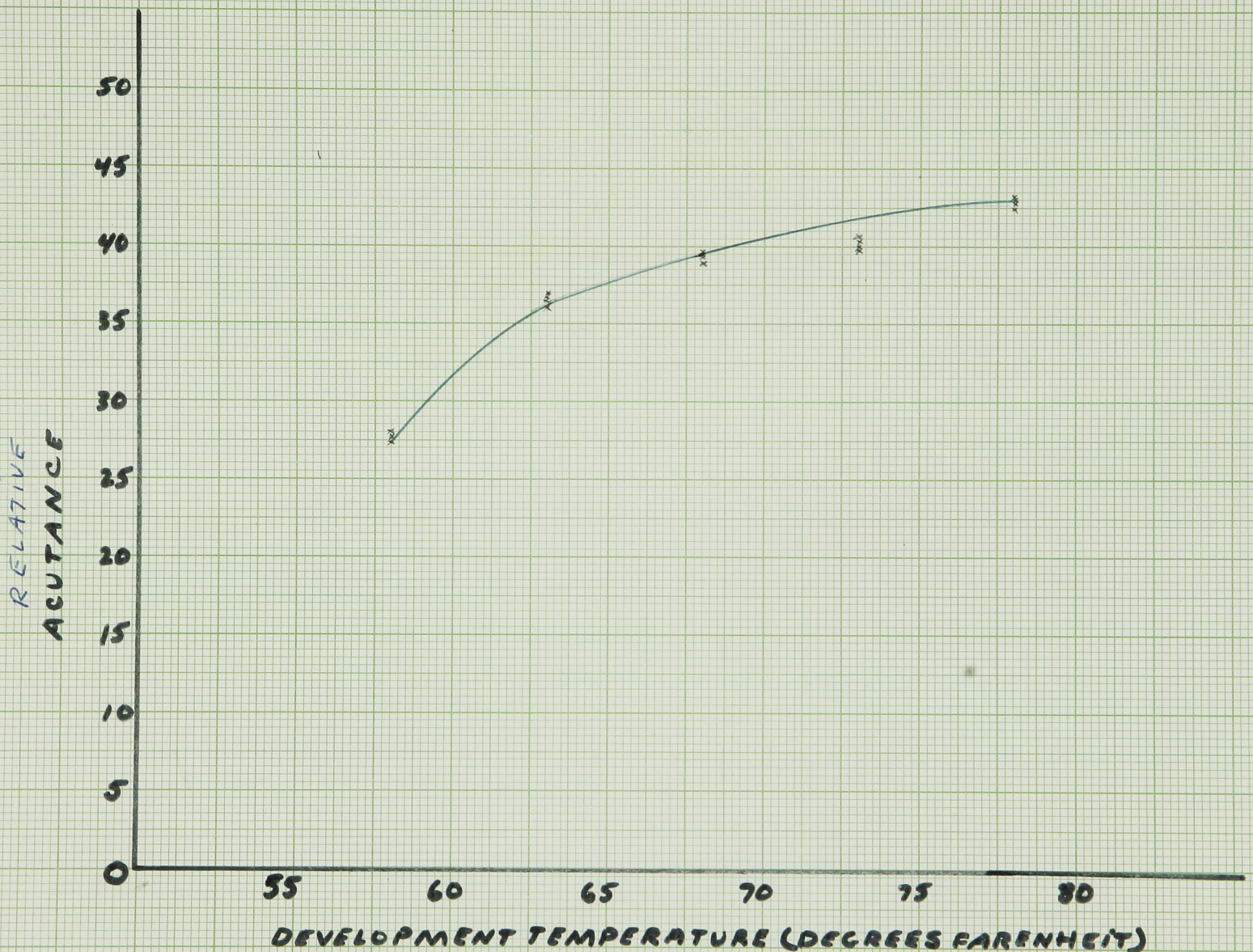
TEMPERATURE	EDGE ONE			EDGE TWO			AVERAGE
58°F	27.6	27.4	27.8	27.5	27.7	27.8	27.6
63°F	36.1	36.5	36.6	37.0	37.1	37.1	36.6
68°F	39.4	39.6	39.4	39.4	39.2	39.4	39.4
73°F	39.8	40.0	40.1	40.1	40.0	39.9	40.0
78°F	42.6	43.4	43.1	42.9	43.0	43.1	43.0

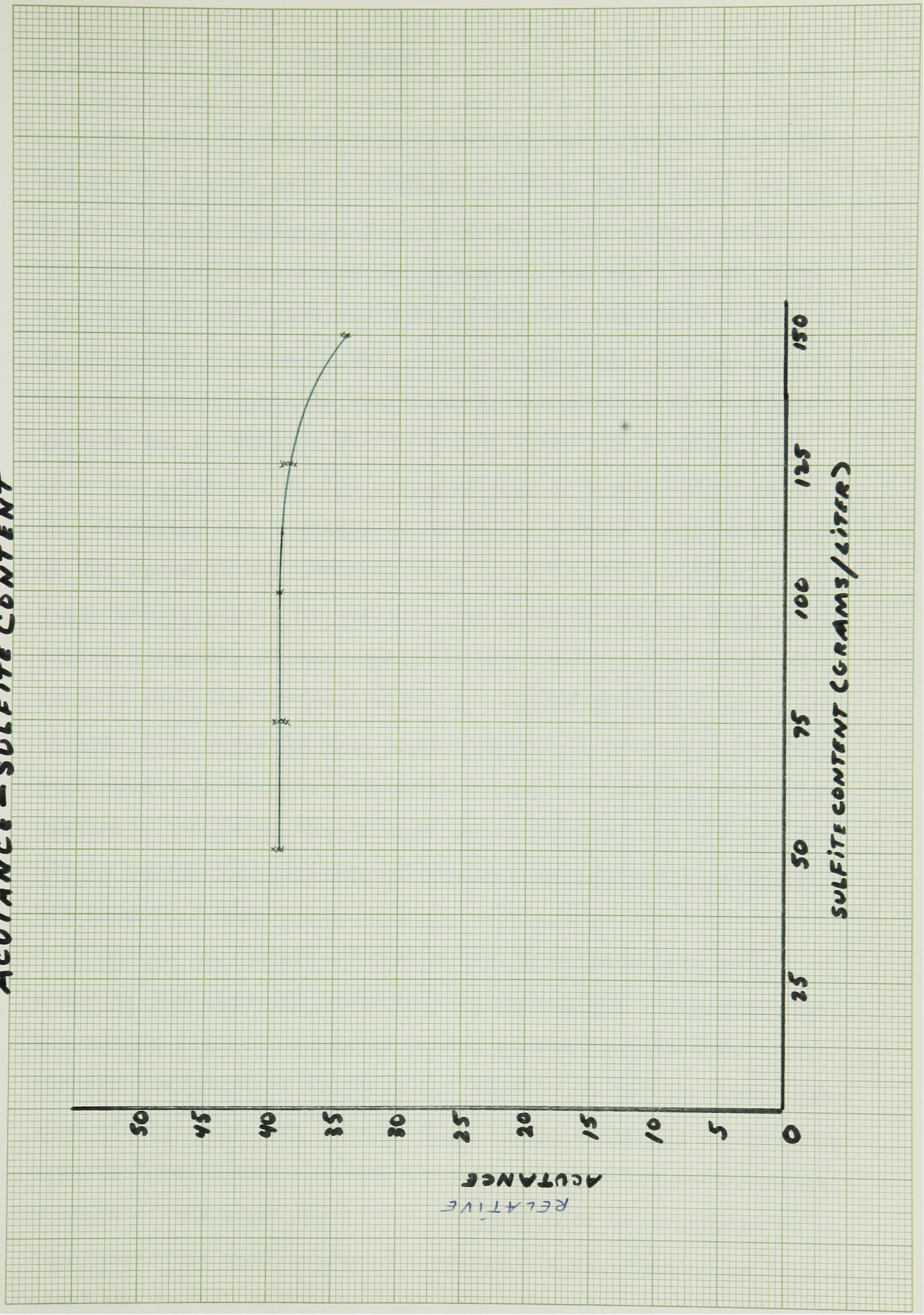
SULFITE CONTENT	EDGE ONE			EDGE TWO			AVERAGE
50 gr/lit.	39.2	39.2	39.4	39.1	39.1	39.2	39.2
75 gr/lit.	39.4	38.6	39.0	39.1	39.0	38.9	39.0
100 gr/lit.	39.4	39.4	39.3	39.5	39.5	39.3	39.4
125 gr/lit.	38.5	38.6	38.4	38.7	38.3	38.5	38.5
150 gr/lit.	34.0	34.2	34.3	34.5	34.4	34.4	34.3

°° Acutance measurements used the value of ΔD on the edge in terms of centimeters instead of microns for ease of calculation.


ACUTANCE - DEVELOPMENT TIME
RELATIVE ACUTANCE
50
45
40
35
30
25
20
15
10
5
0
1
3
5
7
9
DEVELOPMENT TIME (MINUTES)

ACUTANCE — DEVELOPMENT TEMPERATURE




ACUTANCE - SULFITE CONTENT
RELATIVE ACUTANCE
50
45
40
35
30
25
20
15
10
5
0
25
50
75
100
125
150
SULFITE CONTENT (GRAMS/LITER)

Discussion

The data in the preceeding section was obtained from the tracing of images made by contact printing razor blade edges. It was already mentioned that this method was unsatisfactory. The reason for this being the nature of the edge traces. The beginning of the trace was typical of what one might expect but suddenly a break in the trace ocurred and a gradual increase to maximum density was evident. (an example of this appears in the appendix). The resulting trace was assymetrical, that is, a "typical" edge appeared plus a "pseudo-edge" which is definitely not typical. According to J.Eyer[6] this assymetry of the trace is not uncommon when there is contact printing of high density edges. He calls it "an artifact of the contact printing process". He also mentions that this assymetry is not evident when low contrast edges are imaged optically on an emulsion. This suggests that a good method of obtaining knife-edge images is to optically project some sort of low contrast edge onto the film. In any case the experiment did not successfully answer the question of how to best produce a satisfactory edge on film.

Due to the nature of the traces, a satisfactory method of applying the standard acutance calculation had to be contrived. The method decided on was to disregard the "pseudo-edge" and perform the standard acutance calculation on the "typical" portion of the edge. The "pseudo-edge" began appearing at the same density level (near 2.0) and it was felt that the more "typical" portion of the edge was a true indication of what happens to an edge under the various factors tested. In otherwords the "pseudo edge" was unreal and not normal while the "typical" portion was

real and the true indication of what happened to the edge under the conditions tested. The validity of the data and the analyzation of the data is based on the validity of this assumption.

Another obvious characteristic of the traces was the abscence of noticeable edge-effects. The most probable explanation of this is that they are obscured by the nature of the "pseudo-edge". Other possible explanations are the effect of brush development minimized or eliminated the edge-effects and possibly that development was complete enough to minimize or eliminate them.

The acutance values obtained seem to indicate that the factors under test did affect the acutance of the Plus-X film. When development time and temperature are increased, development approaches completion. This factor is probably most influential in the increasing acutance values obtained. The high rate of agitation also makes development go to completion and possibly aids in the increasing acutance values obtained. This factor also might link the relation of edge-effects to acutance because it is generally believed that as development approaches completion edge-effects begin to vanish. Perhaps as this is happening, acutance increases. This possibility was mentioned in the introduction of the report.

Another possibility is that the increasing development time and temperature and high rate of agitation by brush development increased the rate of development(with regards to induction period and diffusion rate) and caused the increase in acutance. In otherwords the higher the rate of development the greater the acutance of the emulsion. This possibility seems to be substtiated by the fact that when sulfite content was increased the acutance decreased. There is really no data on the affect of

increasing amounts of sulfite on the rate of development of conventional developers but according to James and Higgins[7] high sulfite content undoubtably has some effect on development rates. It might be possible that increased amounts retard development rates because of the continuous solvent action on the silver halide grains. This in effect continuosly eliminates grains from being acted upon by the developer. This is just speculation however.

Sulfite also reacts with the oxidation products of development to form sulfonates. This process might also have played a role in the decrease of acutance. The decrease was only evident when amounts in excess of the recommended amount were added. This suggests that the process of sulfite combining with oxidation products was in someway affected. This too is merely speculation.

It was hoped that an equation for each relationship could be formulated by means of regression analysis. This was tried several times and nothing valid was formulated. It can be done, but due to the time factor involved here the effort was terminated. Instead, the curves of relationship were drawn using three points for each level to give a rough estimate of the variance at each level.

Conclusions

The hypothesis is accepted in full. Development time, temperature, and sulfite content did affect the acutance of the emulsion under test.

With increasing development time acutance increased curvilinearly until a maximum value was reached (45.0 at 7 minutes) The next increase to 9 minutes produced an almost negligible decrease or about the same value as was obtained at the 7 min-

ute level. Whether or not this would continue to happen with greater increases in development time cannot be answered here since increased development time was stopped at this point. In general it can be said that increasing development time increases acutance to a maximum value at which point it remains the same or possibly decreases.

Increasing development temperature caused a curvilinear increase in acutance. Beginning at 58°F and stopping at 78°F acutance at first increased rapidly until 68°F was reached and then more slowly until 78°F. What happens beyond this point cannot be answered here since temperature was not raised above 78°F. In general acutance increases with increasing development temperature but a significant gain beyond the recommended 68°F was not evident here.

Increased sulfite content resulted in decreased acutance. This only began to decrease after the normal amount of 100 gr/lit. was exceeded. The greatest rate of decrease ocurred between 125 gr/lit and 150 gr/lit. What happens beyond this cannot be answered here since sulfite level was stopped at 150 gr/lit. In general acutance decreases if the normal amount of sulfite recommended for the developer is exceeded.

References

1. S.P.I.E. Vol.1 number 5,6/7/63, pp. 154-159. "Image Evaluation", by H.N.Todd and R.Zakia.

2. P.S.A. Journal-Photo Science and Technology, vol. 19b, pp. 55-61 (1953), "The Sharpness Of Photographic Images", by Higgins and Jones.

3. Paper presented at the Turin conference "Non-Linear Effects In The Reproduction Of Fine Detail", by H.Frieser. Translated from German by Dr. Carroll.

4. S.P.S.E. Journal, vol. 5, number3, May-June 1961. "Effect Of Developer Composition On The Structure Of Photographic Images" by J.H.Altman and R.W.Henn.

5. Abstracts of S.P.S.E. "Photographic Materials" by C.H.Reece to Ilford Ltd. 1963. "Two-Step Development", British patent 920,310. found in abstracts of S.P.S.E. 1963.

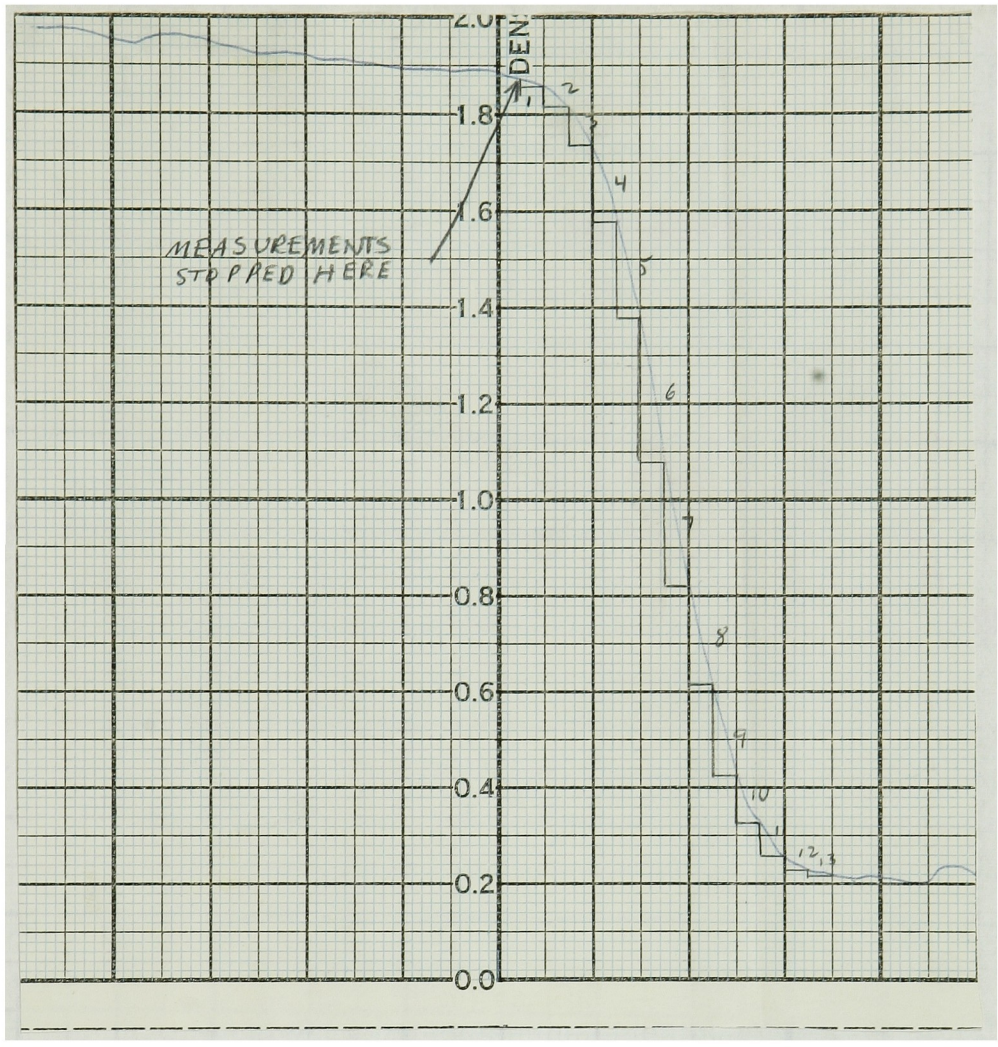
6. J.O.S.A., Vol.48, number 12, p.941, "Spatial Frequency Of Certain Photographic Emulsions", by J.A.Eyer.

7. Fundamentals Of Photographic Theory, p. 141, James and Higgins.

Appendix 1

Ansco Model 4 Densitometer

Scan Speed..25mm/min. Slit # 3 .25x15mm

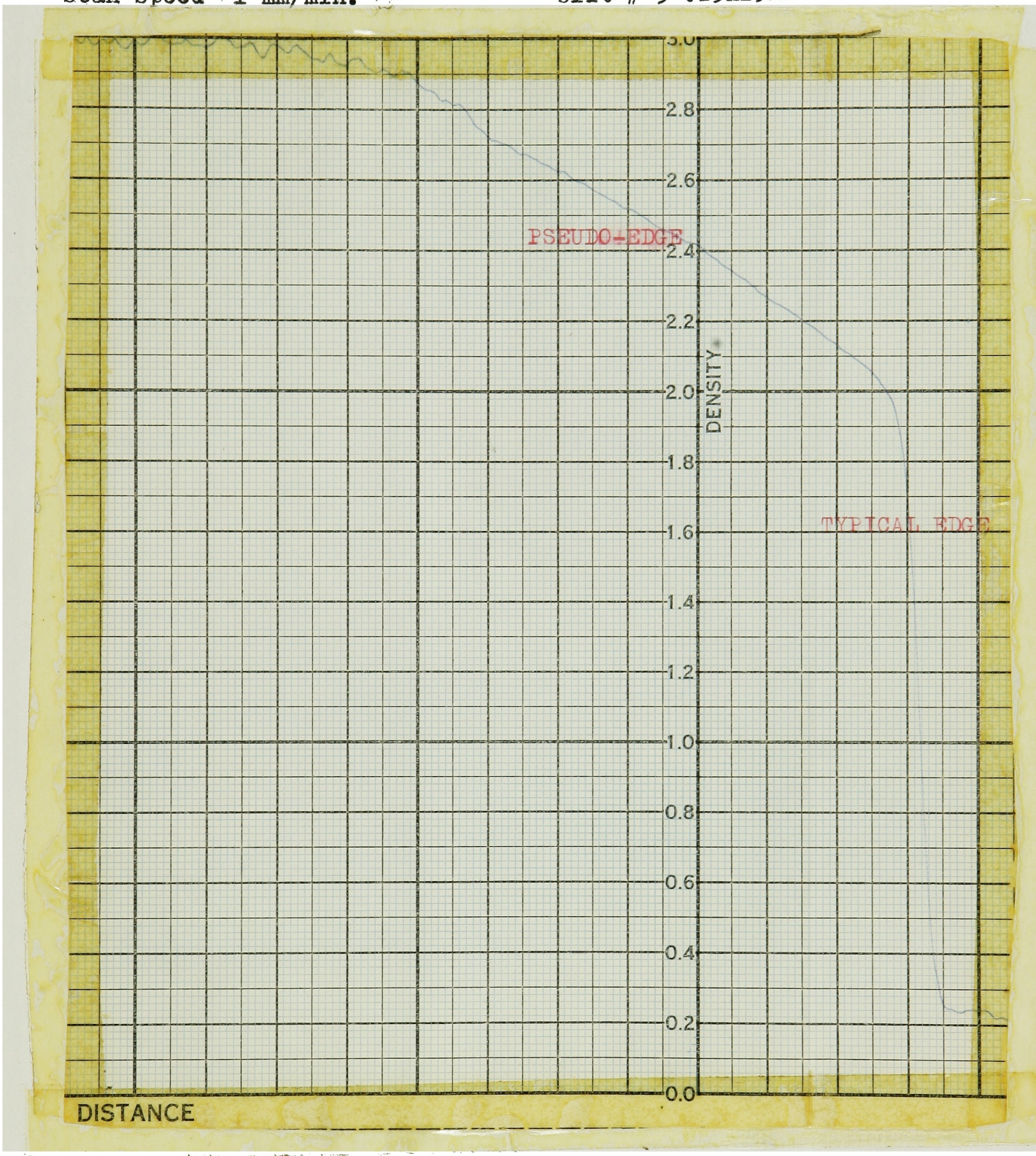


An example of the nature of the trace used to perform standard acutance calculations. Notice that the edge gradients were stopped at the level that the second edge began appearing. This was done in the same way on all the traces

Appendix 2

Ansco Model 4 Densitometer

Scan Speed 1 mm/min. Slit # 3 .25x15mm



This is the example of the appearance of the "pseudo-edge" on traces made by contact printing razor blade edges. Assymetry is quite evident.

References incomplete

Waltzer

Title: plural suggest edge effects in part 1 expt.

Abstract: Leave out third sentence

Intro: First sentence is too positive - ref 2 is old
- see Alfranos 3rd ex 1 mess

2nd P rewrite

Pr last P rewrite

Objectives: Hypothesis incorrectly stated

Secondary ones are not really secondary -

e.g. multiple-edge expts

Procedure: P4 2nd P is contradicted by the work,
e.g. Stuttart reporting on files, which is
not in references

Preliminary expts: wrong tense

P5 — why not factorial expt?

Results

No Statistical Treatment whatever

Alt. #1 - 2nd edge??

C —

Waltzer

Good introduction

p 4 What method is available beside projection and contact?

Note: someone should try contact using a photographic knife edge and a contact liquid such as tetrachloroethylene. What specifically was wrong with contact printing?

Block paint can't be good – too rough.

Changes in processing all will change the density difference – which puts a strain on the acutance formula. For example, what if ~~temperature~~ temperature changes were compensated by time to give equal density difference?

Page 6. What were density differences corresponding to acutance values for different times? What were changes in γ of film?

Good data

Inspection of data for sulfite seem to make it clear that time and temp increased gradient. – There should be data

"Pseudo-edge" was discussed with Nelson; he also is uncertain whether the two emulsion layers are responsible. They looked for such results but were not sure whether they found them. No evidence of adjacency effects – concd, low contrast developer.

Discussion is poor – no mention of the obvious correlation of acutance with contrast

No for presentation at meeting

THIRD QUARTER GRADE

Names Waltzer

Laboratory work

Understanding of problems and intelligence in solution of them

Initiative

Industry

Technique

Notebook

Verbal report

Final report

Introduction: Intelligibility and completeness

Organization of report as a whole

Expression

Quality and quantity of experimental data

Analysis of data:

Logic

Staistical treatment

Conclusions and suggestions for further work:

FINAL GRADE Good use of prelim experiment

How was sample size obtained?

Good data and fair design - but

I cannot see where they used statistical

techniques to milk the data.

No exam term →

THIRD QUARTER GRADE

Names Waltzer

Laboratory work

Understanding of problems and intelligence in solution of them
Poor.

Initiative Fair

Industry ~~Good~~ Satisfactory

Technique Fair

Notebook

Verbal report

Final report

Introduction: Intelligibility and completeness
Good

Organization of report as a whole

Expression

Quality and quantity of experimental data No sonsitometric data for correlation with acutance. Of course acutance increases with δ! Conditions for ~~time and temp~~ ~~density~~ series are not given !!!

Analysis of data:

Logic Poor No discussion of relation of contrast to acutance

Staistical treatment None

Conclusions and suggestions for further work:

FINAL GRADE

D